

Wound Ballistics: Recognizing Wound Potential. Part 1: Characteristics of Missiles and Weapons

Gary W. Dufresne, RN, BSN, CEN

In the United States the number of firearm-related deaths in 1989 was almost equal to the number of motor vehicle-related deaths. Trauma nurses could not imagine themselves caring for motor vehicle crash victims without any understanding of speed, vehicle damage, or collision angles. Gunshot wounds are becoming nearly as frequent as motor vehicle crashes, but the mechanism of injury for a gunshot wound is not as widely understood. This article explains the basics of wound ballistics, emergent care of the gunshot wound victim, and medicolegal concerns for the trauma nurse. (INT J TRAUMA NURS 1995;1:4-10)

Gunshot wounds (GSW) are not simple cases of penetrating trauma. Instead, they are a combination of injuries that result from a blend of blunt and penetrating forces. Not all bullets produce the same type of injury; in fact, similar bullets have the potential to produce a wide variety of wounds that range from minor to lethal. The severity of a GSW will vary, depending on characteristics of the missile, the weapon, and the tissue(s) struck. In 1989 there were 35,150 firearm-related deaths and 47,575 motor vehicle-related deaths in the United States, a difference of only 12,425 lives.¹

The study of the way a missile interacts with target tissue is referred to as *wound ballistics*,²

Gary W. Dufresne is a clinical staff nurse at Madigan Army Medical Center, Emergency Department, Tacoma, Washington.

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and trauma nurses who have a basic understanding of how a gunshot produces injury can benefit in multiple ways. It allows one to have a high index of suspicion for the amount of potential tissue damage, to anticipate the types and priority of medical and nursing interventions, including surgery, and to foresee

potential complications throughout the course of hospitalization, rehabilitation, and follow-up care. This article is the first of a two-part series; "Gunshot Wounds: Tissue Response and Nursing Care" will appear in the next issue of the IN-

TERNATIONAL JOURNAL of TRAUMA NURSING.

MISSILE CHARACTERISTICS

Missiles differ according to *caliber* (i.e., size or diameter, measured in fractions of an inch or in millimeters); *velocity* (i.e., speed at which it leaves the barrel); *line of flight* (i.e., if it deviates from its longitudinal axis); and *construction*. These characteristics help determine two additional factors that increase the severity of injury: the amount of *kinetic energy* re-

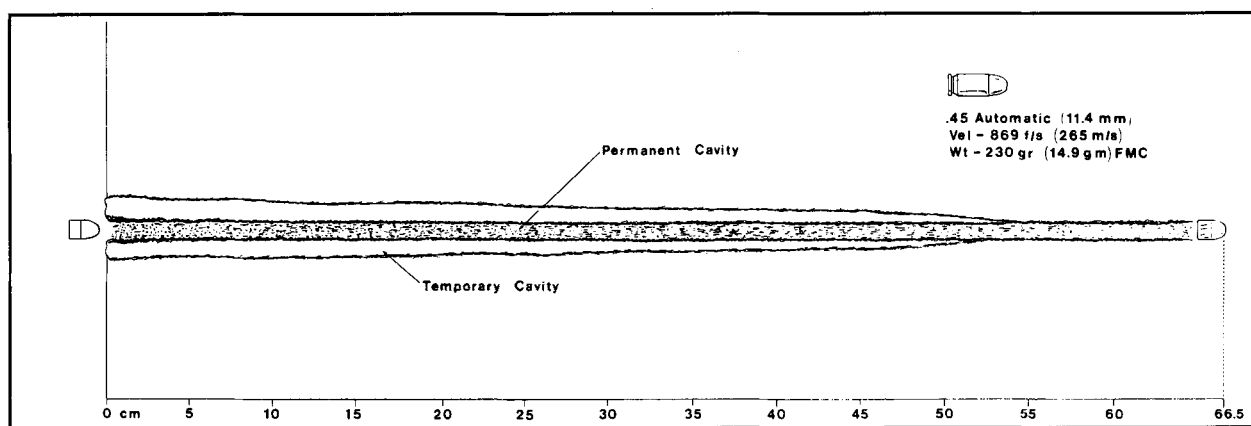


Figure 1. A wound profile of the .45 caliber bullet fired from a low-velocity handgun. The major factor in tissue destruction is permanent cavitation. This profile is typical of most handguns. (From Bowen TE, Bellamy RF. *Emergency war surgery—NATO handbook*. 2nd US rev. Washington, DC: Government Printing Office, 1988:13-34.)

leased to the body, and the size of *cavitation* that occurs.

Kinetic energy (KE) (i.e., energy in motion) is transmitted from the missile on contact with the tissue. The amount of KE that a missile has is determined by its mass and velocity. The greater the KE of a missile, the more potential tissue destruction can occur. The formula for determining KE is $KE = \frac{1}{2} \text{Mass} \times \text{Velocity}^2$ (KE is measured in foot-pounds, mass is weight of missile, and velocity of a bullet is measured in feet per second [fps]). The formula explains that if the mass of an object is doubled, the KE is also doubled. However, if the velocity is doubled, the KE is quadrupled.³ Although the KE of a missile can be significantly enhanced by increasing its velocity, increased KE does not automatically mean that the wound it produces will be proportionally worse.⁴ Other factors, such as missile construction and its potential to fragment, appear to have more influence on the degree of injury. Handguns fire low-velocity missiles, whereas rifles tend to fire high-velocity missiles (Table 1).

Tissue cavitation is the principal mechanism by which a missile produces a wound. As the missile penetrates, the force crushes and produces a path through the tissue, called the *permanent cavity* (Figure 1). The size of the permanent cavity is determined by the caliber (i.e., diameter) of the missile, and its tendency to *yaw* (turn anteriorly along the long axis of the

missile while traveling through tissue). If the missile is traveling with its pointed end forward and its long axis parallel to the longitudinal axis of the missile's flight, this is referred to as 0 degrees yaw. If it has turned so that its entire long axis is perpendicular to the longitudinal axis of the missile's flight, this is considered 90 degrees yaw. Once the missile turns beyond 90 degrees, it has begun to *tumble*.² One can appreciate the greater size of a permanent cavity created with a missile that has a large degree of yaw (Figure 2).

How soon yaw and tumbling occur after the missile strikes tissue will be an additional factor in determining wound severity. The average high-velocity missile does not begin to yaw and tumble until it has penetrated tissue by 15 cm, and it does not produce maximum temporary cavitation (see discussion that follows for description of temporary cavity) until it has penetrated approximately 25 cm. The average adult human thigh is 12 cm in diameter; thus a through-and-through high-velocity missile extremity wound that misses bone will probably not produce more than a limited-size "ice pick" type of permanent cavity. This is not true of the chest or abdomen, where the distance for a missile to travel does allow for yaw and maximum temporary cavitation.⁵

In addition to the permanent cavity, a missile traveling through tissue impels surround-

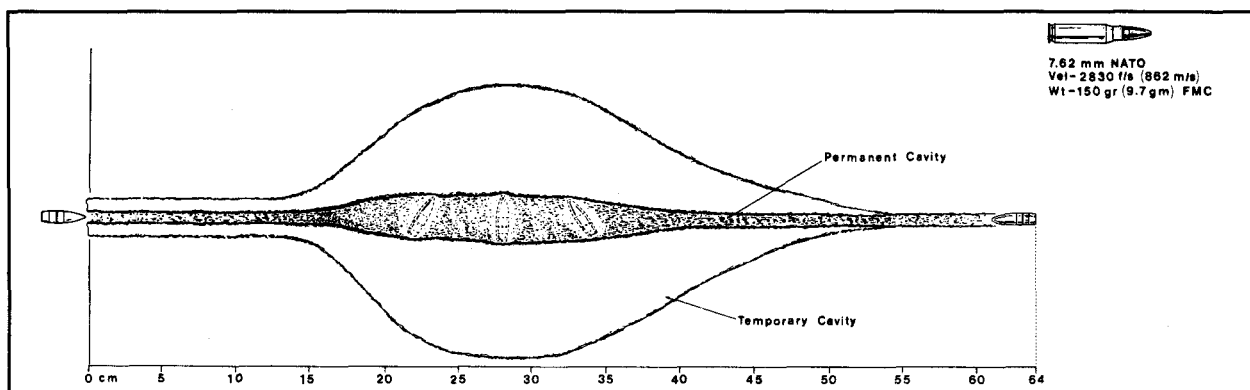


Figure 2. A wound profile of the NATO 7.62 mm bullet. The larger permanent and significant temporary cavity is typical of those produced by high-velocity, nondeforming bullets. (From Bowen TE, Bellamy RF. Emergency war surgery—NATO handbook. 2nd US rev. Washington, DC: Government Printing Office, 1988:13-34.)

ing tissue outward along its path, producing a radial stretch² (see Figure 2). *Temporary cavitation* can be compared to a diver entering water.^{4,5} If the water is entered aerodynamically and nearly perpendicular, there is little or no splash, and a minimal amount of water is displaced. This correlates to a low-velocity, nondeforming, nonfragmenting missile that does not deviate from its longitudinal axis. If the same diver deviates from his perpendicular longitudinal axis, even slightly, he will create a bigger splash. The amount of water displaced is proportional to the degree of deviation from perpendicular. Generally, a low-velocity missile does not create a significant temporary cavity.^{4,5}

The size of the temporary cavity produced by a missile in tissue can also vary. It is estimated the largest it may be is approximately 11 times the diameter of the missile.⁴

Because temporary cavitation is such a short-lived event, one may not consider it a significant factor in causing tissue damage unless sensitive tissues are involved. In practice, it has been attributed as the cause of distal blood vessel disruption and, infrequently, skeletal fractures.⁴

Missile construction is a major determinant

of how destructive a GSW may be. Although the caliber and velocity of a missile are important, they are not as significant as if the missile *deforms* or *fragments*.⁶

A missile is made with a lead core, which is then coated with a harder metal, usually copper. The outer layer is referred to as the “jacket.” When the entire missile is coated, the outer layer is referred to as a “full metal jacket.” A missile that

either has no jacket at the tip or has a hollowed-out tip is called a “dum-dum,” “hollow point,” or “soft point.” This feature allows the missile to deform (e.g., assume a mushroom shape) on striking tissue and increases the amount of KE transferred because it does not easily pass through the target.⁶ De-

forming missiles are more destructive than a full metal jacket missile of either high or low velocity because they produce a large temporary cavity, crush more tissue because of their mushroom shape, and produce more fragmentation than full metal jacket ammunition. Because these unique characteristics occur immediately on tissue penetration, deforming missiles are devastating regardless of penetration depth.⁵⁻⁷

If the diver analogy is used again,^{4,5} when the diver chooses a “cannonball” dive (i.e., has

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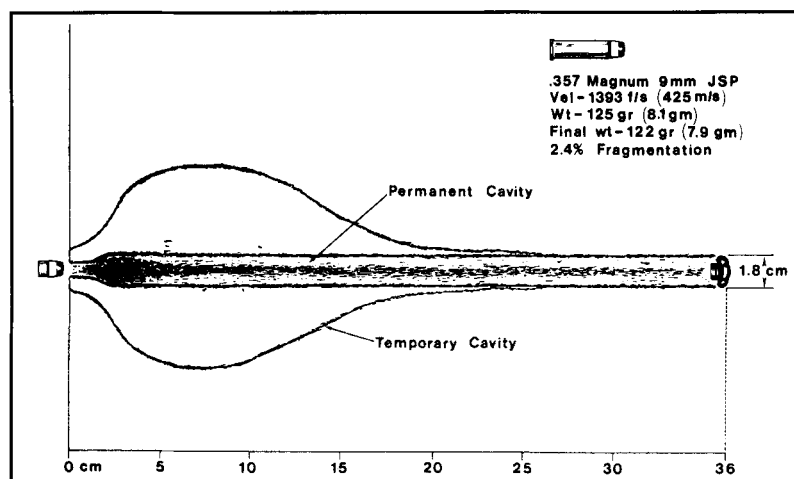


Figure 3. The .357 Magnum soft-point bullet “mushrooms” almost immediately, crushing more tissue and creating a large temporary cavity before reaching 15 cm (compare with Figure 2). (From Bowen TE, Bellamy RF. Emergency war surgery—NATO handbook. 2nd US rev. Washington, DC: Government Printing Office, 1988:13-34.)

his arms and legs flexed close to the body to create a larger diameter), he will create a larger splash immediately on entering the water. This is similar to a missile that assumes a larger diameter (“mushrooms”) when coming in contact with tissue (Figure 3).

Deforming missiles are used in civilian firearms, such as handguns and hunting rifles, and by police. The Hague Convention of 1899 forbids the Armed Forces from using deforming missiles in military combat. Hollow-point ammunition is used in game hunting to ensure a quick and humane death for the hunted animal. Consequently, the index of suspicion and the potential for tissue destruction are much higher for hunting accidents.⁷

Hollow-point missiles also tend to fragment, which serves to increase wounding potential. If portions of a missile break or peel off on striking tissue, the smaller fragments will become small projectiles, described as secondary missiles. The fragments radiate through tissue from the centrifugal forces of missile rotation. As each fragment is flung, it creates additional areas of permanent cavity and makes

affected tissue more susceptible to temporary cavitation.⁷ Missiles of very high velocity (e.g., greater than 3000 fps) that also fragment produce more severe wounds.²

There are two important exceptions to which missiles can be expected to fragment: (1) Despite the use of a high-velocity, full metal jacket missile, portions of the jacket of a military M-16 rifle and its civilian counterpart, the AR-15 (Figure 4) will peel away from the bullet. This has been considered the cause for greater tissue disruption produced by the M-

16 rifle.⁴ (2) If a missile strikes bone, it is likely to fragment. This is true with virtually all types of missiles.

WEAPON CHARACTERISTICS

The choice of weapon will influence primarily the velocity of a missile and potentially the amount of KE delivered. Missiles that travel at a speed of approximately 1100 fps are considered low velocity, whereas a high-velocity missile travels more than 2000 fps.^{7,9} A rifle's muzzle may be able to fire a missile two to three times faster than a handgun (Table 1). In the past, civilian trauma centers in the

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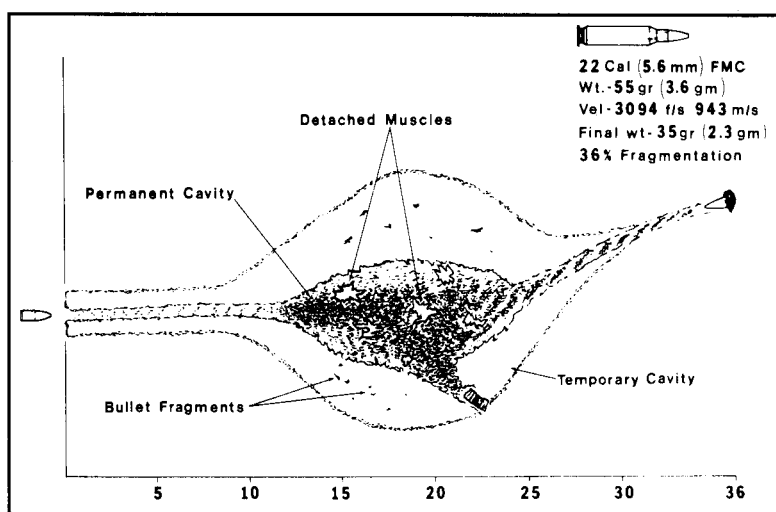


Figure 4. The destructiveness of the M-16 5.56 mm bullet is due to its high velocity and fragmentation rather than tumble and yaw. The civilian AR-15 will produce a similar profile. (From Bowen TE, Bellamy RF. Emergency war surgery—NATO handbook. 2nd US rev. Washington DC: Government Printing Office, 1988:13-34.)

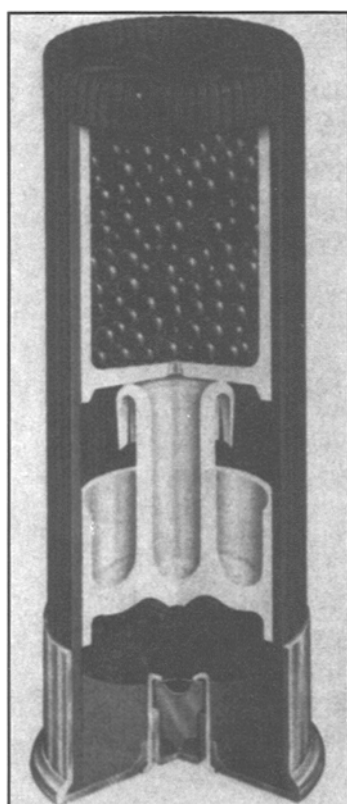


Figure 5. Cross section of Federal birdshot shell. (Used with permission of DiMaio VJM. Gunshot wounds: practical aspects of firearms, ballistics, and forensic techniques. Boca Raton, Florida: CRC Press, 1985.)

Table 1. Commonly used weapons and their velocities

Weapon/cartridge*	Velocity† (fps)
Handguns	
.38 Special	855
.45 Automatic	855
9 mm Parabellum	1223
.357 Magnum	1393
Military rifles	
5.56 mm NATO (M-16/AR-15)	3094
7.62 mm NATO (AK-47)	2340
Hunting rifles	
30-30 Winchester	2220
30-06 Springfield	2700

*Most weapons in the United States are defined by the size or caliber of the bullets they fire (i.e., a .38 Special fires a .38 caliber bullet measuring .38 inch).

†The above velocities are general approximations and will vary with increased gunpowder loads.

United States have treated victims of low-velocity handgun wounds and, on occasion, victims of wounds caused by hunting rifles. The increased availability of high-velocity automatic and semiautomatic weapons is now changing the types and severity of GSW injuries being treated. High-velocity missiles have the potential to destroy more tissue because

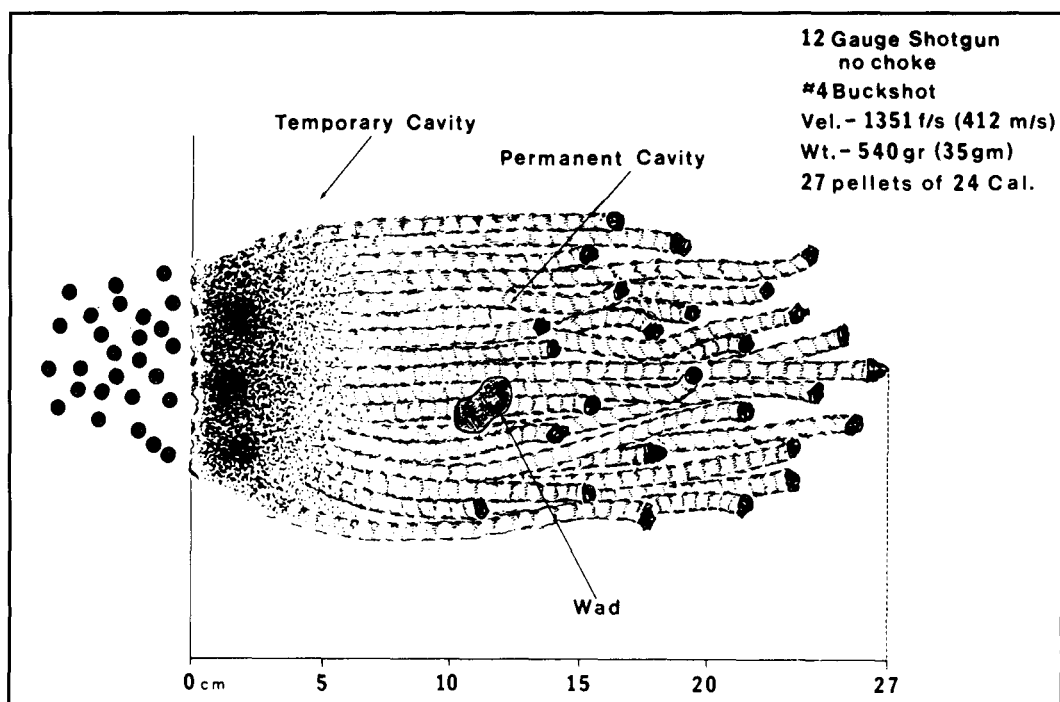


Figure 6. A close-range 12-gauge shotgun wound involving No. 4 buckshot. The tightly clustered pellets produce an enormous amount of crushed tissue. The presence of wadding signifies a close-range injury. (From Bowen TE, Bellamy RF. Emergency war surgery—NATO handbook. 2nd US rev. Washington, DC: Government Printing Office, 1988:13-34.)

of their higher KE and their tendency to yaw, tumble, and fragment. Despite the high-velocity missile's potential for destruction, handguns are still lethal weapons. When deforming missiles are used, low-velocity missiles can produce more tissue destruction than high-velocity missiles that do not have sufficient time to yaw or tumble.

SHOTGUN WOUNDS

Shotgun wounds are unique because of the way shotgun shells are constructed and the importance of range from gun to victim.

Construction of Shells

Shotgun shells have a totally different construction than handgun or rifle missiles (Figure 5). They are composed of a *primer*; a *charge*; *over-the-charge wadding* (helps stabilize pellets to prevent excessive spreading; formerly made of felt); *shot* (pellets); *filler*; and *over-the-shot wadding*. The modern shell replaces wadding and

filler with a single plastic casing that is crimped at the top. Fragments of this casing found in a wound are still referred to as wadding.^{10,11}

In general, the size of a shotgun shell is standardized; the system that describes it by *gauge* is antiquated. Gauge refers to the number of pellets (lead balls) that it would take to equal 1 lb when placed in a gun barrel of given diameter. For example, the most common size of shotgun in the United States is a 12 gauge (Figure 6). This means that 12 lead pellets, each weighing $\frac{1}{12}$ lb (38 gm), would equal 1 lb (450 gm) when placed in a gun barrel of a specific size.^{10,11}

The size of the pellets can also vary. Generally, the higher the shot number, the smaller the size of the pellets. "Birdshot" (used for small targets such as fowl) pellet size ranges from 0.05 inch to 0.14 inch (1.3 mm to 3.6 mm) in diameter, Number 12 to Number 3 shot, respectively. "Buckshot," intended for larger game such as deer, uses a larger pellet. "Slugs" are used for more powerful targets, such as bear.^{10,11}

Importance of Range

When a shotgun shell is fired, it will break apart and the outer layers will fall away, allowing the pellets to separate radially, spread in a cluster, and become less aerodynamic as they pass through air. Pellets lose velocity and KE as they travel from the weapon to the target.

The closer the victim is to the shotgun, the less time there is for the shell to break apart and the pellets to lose KE and to spread. A very close-range shotgun wound will have a concentrated mass of pellets and there may even be shell wadding or plastic casing in the wound.^{10,11}

Shotgun wounds are classified according to their range (defined in number of yards/meters from muzzle to target).^{9,10} A Type 0 and I wound occurs with a range of greater than 7 yd (12 m). Such wounds tend to involve the subcutaneous tissue and also deep fascia in Type I. Type II wounds are sustained in a range of 3 to 7 yd (5 to 12 m) and have deeper pellet penetration of tissue. Type III wounds are close range, less than 3 yd (5 m), and are the most severe. Close-range shotgun wounds involve massive local destruction and are equivalent to high-velocity gunshot wounds. They are recognizable by the small entrance wound (i.e., pellets have not had as much time to disperse) and possibly by the presence of wadding in the wound.¹¹ If pellet size is increased along with range, the destructive effectiveness can be maintained (i.e., 00 buckshot of which there are nine pellets in a shell and each equivalent to a .22 caliber bullet is effective from greater than 7 m and should be considered as multiple .22 caliber handgun wounds).¹⁰

Shotgun pellets are designed to penetrate tissue, transfer KE to the victim, and, unlike other types of GSW, rarely exit the body. When a missile does not exit the body, all of its KE has been transferred to the target tissue. This is why close-range shotgun wounds can be devastating to all body tissue. Shotgun pellets are likely to produce devastating neurologic and vascular damage in an extremity and hemor-

rhage, regardless of target tissue. Shotgun pellets also tend to carry environmental contamination, such as wood, glass, clothing, or shell wadding, into the wound. Unlike other GSW, all shotgun injuries require meticulous exploration, debridement, irrigation, and removal of environmental contamination but not necessarily thoracotomy or exploratory laparotomy.^{5,11}

"Gunshot Wounds: Tissue Response and Nursing Care" will appear in the next issue of the INTERNATIONAL JOURNAL of TRAUMA NURSING. The upcoming article will address tissue characteristics and the implications for trauma nurses.

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